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Real Representations of Ancient Greek Technology

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Abstract : *The aim of the present article is to present an analysis of some of the exhibits in an interesting exhibition in an arts center of Athens, Greece about operating models of ancient Greek and Byzantium inventions. All the exhibits come from the Kotsanas museum of Ancient Greek technology in Katakolon, a small port close to Ancient Olympia.*

Keywords: *Ancient Greek technology*

I. Introduction

The contribution of ancient Greeks to philosophy, architecture, and mathematics is well known. However, the technology developed in ancient Greece not widely spread. The famous Antikythera calculating mechanism (the first calculating machine of the history) is only one example of an ancient Greek machine [4].

In the small port of Katakolon in west part of Peloponesse, Greece, approx. 20mi from Ancient Olympia, there is an interesting museum of ancient Greek technology [5]. The museum was founded and organized by the engineer and high-school teacher Konstantinos Kotsanas, who has spent a major effort for the study and reconstruction of inventions from ancient Greek technology. His studies with clear explanations and pictures are included in his three books [1], [2] and [3].

The exhibition in Katakolon includes approximately 300 operating models of ancient Greek as well as early Byzantium inventions. It constitutes an important contribution to the history of ancient Greek technology. Many technological marvels are exhibited (from the robot - servant of Philon to the cinema of Heron and from the automatic clock of Ktesibios to the analog computer of Antikythera), covering the period from 2000 BC until the end of the ancient Greek world. All were constructed by Kotsanas, through 22 years of extensive research and study. It is a quite credible exhibition, since it is based solely on the thorough study of the ancient Greek, Latin and Arabic literature, vase painting information and minimal relevant archeological finds), with very accurate references to the original sources.

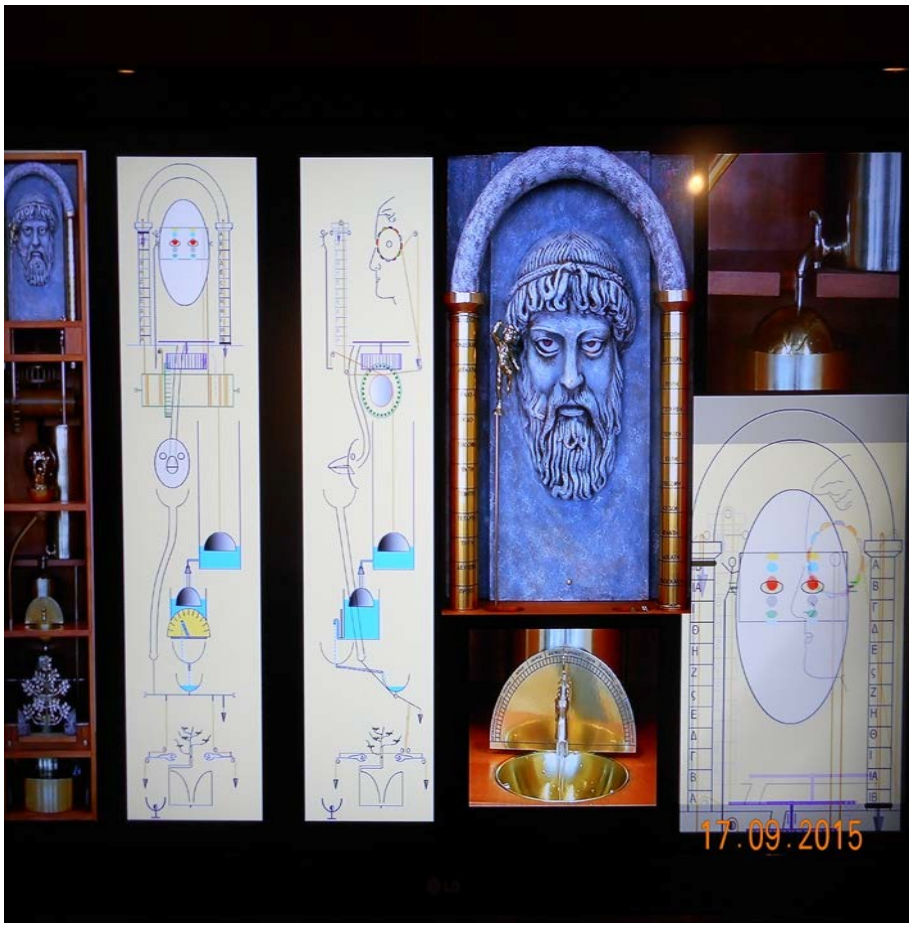
The aim of the museum is to highlight unknown aspects of ancient Greek civilization and to prove that the technology of the ancient Greeks, just before the end of the ancient Greek world, was shockingly similar to the beginning of our modern technology. The bolts and nuts, gears and rules, pulleys and belts, sprockets and chains, block and tackles and winches, hydraulic controllers and valves are just some of the inventions of the ancient Greeks which were the foundations of their complex technology. Parts of the permanent Katakolon exhibition often moves to various parts of Greece and it was recently hosted in the Annex of the Museum Heiraklidon (Science, Technology and Mathematics) in Athens [6], which is located in the Thission area, very close to the Acropolis (Picture 1).

Picture 1. The Museum Heiraklidon Annex.

The exhibits are organized in 24 thematic categories, which are the following: The automatic theaters of the ancient Greeks, the clocks of the ancient Greeks, the automatics of Heron, the automatics of Philon of Byzantium, the mythical automatics of the ancient Greeks, the inventions of Ktesibios, the inventions of Archimedes, the elevating mechanisms of the ancient Greeks, the technology of the ancient Greek theater, the hydraulic technology of the ancient Greeks, measuring instruments, tools and machines, telecommunication, astrological measuring instruments, siege technology, textile technology, agricultural technology, medical technology, sport technology, nautical technology, flight machines, musical instruments, toys, measurements with man as measure, and geometric kinematic mechanisms of the ancient Greeks. The aim of the present article is to present some of the exhibits selected from the above thematic categories, through personal pictures taken (by permission) from the Museum Heiraklidon.

II. The hydraulic clock of ktesibios (picture 2)

It was a marvel of automation, since the clock was able to operate continuously, without human intervention, indicating the 365 different hours of the year. The water from a spring supplied, through a spillway, the upper bronze container. This, in turn, supplied the smaller intermediate container which was a constant level controller through a system it contained (a conical valve on the float to interrupt the flow). Then a dripper supplied the tall bronze container, drop by drop, with a constant water supply. With the rising of water in it, the float rose and, through a shaft, a statuette with a pointer rose at the same pace. The pointer indicated the hour of 24 on a rotating drum containing a trace of hours of day and night depending on the date. At the end of the 24 hours, the water exceeded the side-built siphon and drained rapidly. On the descent of the float an ingenius drive system was activated in the ratio of 1 in 365 (which consisted of a toothed rule, a pawl, two gears and a worm gear) that ensured the rotation of the drum calibrated in 1/365 of its circumference as the pointer of the statuette now indicated the exact time of the next day.



Picture 2. The hydraulic clock of Ktesibios.

III. The Repeating ("Polybolos") Catapult Of Dionysios Of Alexandria (Picture 3)

It was an automatic repeating straight-spring catapult which had the possibility of launching arrows in succession and constituted the leading achievement of ancient Greek catapult engineering. The catapult was realized for the Rhodians. It was equipped with a turning roller that had two grooves (one lengthwise and one helical) and a wooden case that held the launch arrows. Also at both sides of its case it had two pairs of pentagonal sprockets (gears) that were connected with a wooden chain. A pin on each chain was connected at the same point with the slider of the catapult. The slider had a bent axle with its end entering the helical groove of the roller above. With the right rotation (by the operator of the weapon) of the handspikes at the rear sprockets the slider moved automatically forwards, the roller turned left automatically until the lengthwise groove was aligned with the corresponding opening of the arrow case and then an arrow fell into the groove of roller. At the same time the string entered automatically into the claw of the slider and a stable pin pushed the trigger automatically and locked the claw. With the left rotation of the sprockets the slider moved automatically backwards, the roller turned right automatically until the lengthwise groove was aligned with the receiver of the slider and the arrow fell automatically into this. At the same time a stable pin pressed the trigger automatically and the claw was lifted. Then the string was released automatically and the arrow was launched. With the continuous backward and forward movement of the handspikes in this way and in minimal time the operator launched in succession the all arrows of magazine. SOURCES: "Philon of Byzantium, Belopoietica", "Heron of Alexandria, Belopoietica".

Picture 3. The repeating ("polybolos") catapult of Dionysios of Alexandria.

IV. The Pythagoras Cup (Picture 4)

It was an ingenious wine cup which had a line that determined the limit of fulfillment and an axial or curved siphon. When one filled it excessively, the level of liquid covered the siphon and emptied automatically. It is considered an invention of Pythagoras (6th century BC) who wanted to teach his students the necessity of complying moderation in our lives. It is also called the cup of justice because it reflects the basic principles of justice (vituperation and vengeance). When the limit was exceeded (vituperation), lost was not only that which exceeded the limit but also that which had been acquired up to then. SOURCE: "Heron of Alexandria, Pneumatica".

Picture 4. The Pythagoras cup.

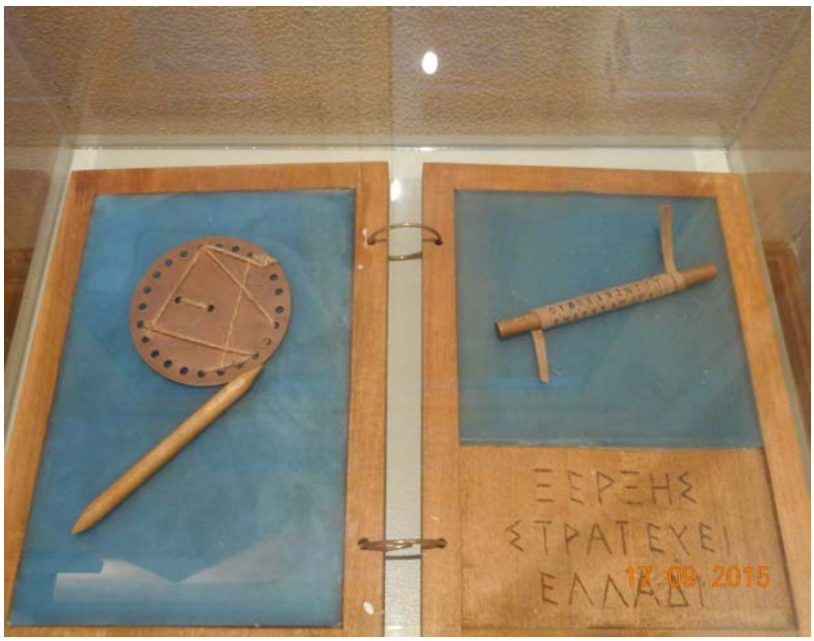
V. Three Cryptography Devices (Picture 5)

a) Twofold waxed plates

Wooden plates with their inner surface slightly curved and covered with black wax. A special wooden stick (with a pointed end on the one side for writing the message and a flat end on the other for erasing it) was used to engrave the message on the waxed surface with normal or cryptographic letters (i.e. with the use of dots instead of vowels, mirror writing, etc.), or in special cases under it (i.e. the message of the exiled Spartian Dimaratos in the Persian palace: "Xerxis is going to attack Greece". SOURCES: "Homer, Ilias, Z 156", "Apollodoros, II 3. 1", "Herodotos, Histories, I", "Polydeukis, Onomastikon, X57", "Aristofanis, Nefelai".

b) Aeneas' cryptographic disc :A disc with 24 holes (one for each letter of the alphabet) on the periphery, one in the centre and one more defining the letter "A". The sender formed the message by passing a thin thread through the holes of the relevant letters and the receiver read it by removing the thread and noting the letters from right to left. SOURCE: "Aeneas, Poliorkitika, 31".

c) Cryptic relay (Laconian) : A thin band (3mm) of cultivated leather rolled around a wooden cylinder, on which the sender would write the message and the receiver would read it by unrolling it onto a piece of wood of equal diametre. On this specific relay we can read the desperate message sent by the Laconians to Sparta after their defeat in the naval battle of Arginouse: 'the ships are lost, Mindaros is killed, the men are starving, we don't know what to do!' SOURCE: "Plutarch, Lives parallel (Lysandros), 19".



Picture 5. a)Twofold waxed plates, b) Aeneas' cryptographic disc and c) Cryptic relay (Laconian).

VI. The Ingenious Wine-Jug Of Philon (Picture 6)

It was a jug (conception of Philon of Byzantium) from which water, wine or watered- wine, depending on the will of cupbearer, was poured automatically. It consisted of a vertical diaphragm that separated the jug into the compartments of water and wine and the outlet fluid pipes which, however, were found one inside the other so that outside the jug they appeared as one. The jug had an airtight lid which made it impossible for the fluids to flow at its inversion because of the vacuum that was created by the inability to substitute the outlet fluids with air. Two tubes began in the middle of the jug and reached the neck so that they formed its handle. At the sides of the tubes there were air holes which the cupbearer covered with his finger. With the combinational disclosure of the air hole of the water compartment, wine compartment or even the two simultaneously, the cupbearer allowed the incoming air into the corresponding compartments and the flow of water, wine or watered-wine according to the wish of the visitor. SOURCES: "Philon of Byzandium, Pneumatics".

Picture 6. The ingenious wine-jug of Philon.

VII. The Hydraulic Endless Screw Of Archimedes (Picture 7)

This is a mechanism for pumping water with a small difference in height still used today for transporting fluids or granular materials. It consisted of a wooden shaft which had eight convolutions (curves) of thin and flexible willow or wicker branches (one stuck on top of the other) so that a screw of eight beginnings was created. The screw worked within a wooden pipe. The device was placed in the water with an inclination of 30 degrees. With the manual rotation of the screw, the water (trapped within its coils) rose and flowed from the mouth of the pipe. SOURCE: "Vitrouvius, On architecture X".

Picture 7. The hydraulic automaton of the «chirping birds» and of the «returning owl».

VIII. The Hydraulic Automation Of The "Chirping Birds" And The "Returning Owl" (Picture 8)

It was a conception of Philon of Byzantium (which was improved by Heron of Alexandria) depicting birds chirping when an owl turned away from them and they stopped when it turned towards them. Automatically, the theme was repeated continuously. For the operation of the automaton, water from a spring was driven inside the upper airtight container forcing the air to leave through a pipe. Because the pipe-flute

led to water, the oscillating wavelength produced a chirp with notes of different frequency. Then when the water level exceeded the curved siphon of the container, it emptied through it to the intermediate container, diverting a yoke to the side. This forced the built-in rotating shaft supporting the owl to turn towards the birds that then stopped chirping. When the water level exceeded the axial siphon of the intermediate container, it emptied through to the lower container, diverting the yoke towards its counterweight, which caused the owl to turn away from the birds that

then began to sing again, etc. SOURCES: "Heron of Alexandria, Pneumatics, A 16", "Philon of Byzantium, Pneumatics, 61".

Picture 8. The hydraulic automation of the "chirping birds" and the "returning owl".

IX. The Alarm Clock Of Plato (Picture 9)

The upper ceramic vessel supplies the next vessel through an (appropriately calculated for every case) outflow funnel. When the second vessel becomes full at the programmed moment through the internally located axial pipette, it evacuates fast towards the next closed vessel and forces the contained air to come out whistling through a tube at its top. After its function, the third vessel empties slowly (through a small hole located at its bottom) towards the lower storage vessel in order to be reused.

Picture 9. The alarm clock of Plato.

X. The Mobile Automatic Theatre Of Heron Of Alexandria (Picture 10)

A precise reconstruction of Heron's mobile automatic theatre which presents the myth of Dionysos.

Act 1:The mobile theatre moves automatically to another programmed position (doing compilations of rectilinear and circular movements).

Act 2: Fire is lit on the altar in front of Dionysos. Water springs from his holy stick and wine from his cup is poured onto the small panther.

Act 3: The place around the four columns of the base is crowned with flowers. The sound of drums and cymbals are heard while the six Bacches move dancing around the temple.

Act 4: The musical instruments stop and Dionysos turns to the other side of the temple. The winged Niki (Victory) turns with him.

Act 5: Fire lights on the other altar of the temple and from his holy stick, water springs again and from his cup, wine is poured onto the small panther.

Act 6: The sound of drums and cymbals are heard again while the six Bacches move backwards dancing around the temple.

Act 7: The musical instruments stop and the mobile theatre moves automatically to its initial position (by moving backwards doing compilations of rectilinear and circular movements).

All of these are accomplished automatically by the movement of tens of metres of wisely mechanically timed (=programmed) threads that are pulled from the force of a lead weight which fall at a steady pace in a clepsydra with grain (millet). With the clockwise, the releasing and the counter-clockwise winding of threads around axles and reels, the following is accomplished a) the forward movement (rectilinear or circular) of the automatic and the clockwise turns of the mechanisms, b) stillness and c) the backward movement (rectilinear or circular) of the automatic and the counter- clockwise turns of the mechanisms. To start the show, the rope from the front side of the base needs only be pulled. SOURCE: "Heron of Alexandria, Automatopoetike".

Picture 10. The mobile automatic theatre of Heron of Alexandria.

XI. The Automatic Servant Of Philon (Picture 11)

Maybe the first operating robot of humanity. This was a human-like robot in the form of a maid which in her right hand held a jug of wine. When the visitor placed a cup in the palm of her left hand, she automatically poured wine initially and then she poured water into the cup mixing it when desired. Description of the operation: Inside the maid, there are two airtight containers (with wine and water, respectively). At their bottom there are two tubes leading their content through her right hand to the lip of the jug of wine. Two air pipes start at the top of the containers, go through their bottom and lead curved into her stomach. Her left arm is linked, through the articulation, to her shoulders, while a winding rod (spring) that is positioned in extension of the restraining rod raises it. Two pipes start at the same point (joint) and come down (going through and freeing the curved perforated ends of the air pipes). The pipes of the joint have two holes or tears at their ends, with the hole in contact with the container of wine preceding that which is connected with the water container. When the cup is placed into the maid's palm, her hand comes down and the tubes of the joint are lifted. The hole in one pipe is aligned with the air pipe of the wine container, air enters the container and wine flows from the tube into the cup. When the cup of wine is half- full, the hand (due to weight) descends further, the passage of the air pipe of wine obstructs and the flow stops. At the same time the other tube is aligned with the air pipe of the water container and it begins to flow thus diluting the wine. When the cup is full, the hand (due to weight) descends further, the passage of the air pipe with water obstructs and the flow stops. Also, if the cup is removed at any moment, the left hand rises, the tubes of the joint descend, cutting off the air pipes, creating vacuum in the containers and stopping the liquid flow. The maid then fills the cup with wine or diluted with water of desired quantity depending on the time it is pulled from her palm. SOURCE: "Philon of Byzandium, Pneumatics".

Picture 11. The automatic servant of Philon

Further descriptions as well as interactive presentations of all models can be found in [5].

XII. Conclusion

It was a short presentation of some of the functional models about Ancient Greek Technology in the Kotsanas museum in Katakolon, Greece. It is indeed unexpected that a big number of today's technology can be traced back to Ancient Greeks and Byzantins. By studying such devices one can extract useful historical information about the way of life and the science developed in the antiquity and medieval times.

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